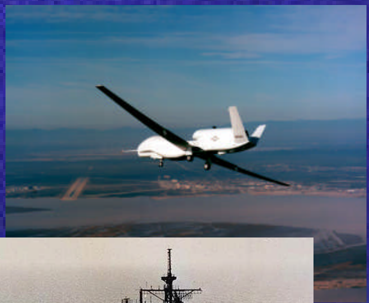
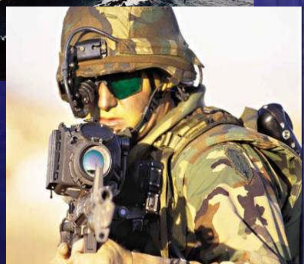
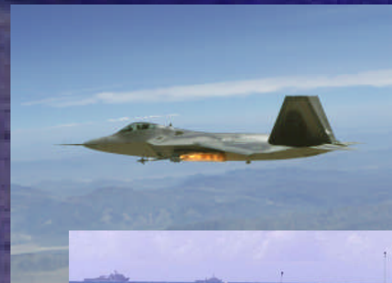
Office of the Secretary of Defense

Defense Microelectronics Activity (DMEA)





Impact of RoHS and WEEE on Military and Aerospace Applications



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NASA/C3P – 2008
International Workshop on Pollution Prevention and Sustainable Development
University of California at San Diego
20 November 2008

Outline

- Background
- Microelectronics challenges
- Global electronics market
- Lead-free impacts on military/aerospace
- Conclusion

Background

There is a global transition to Lead-free

- **Reduction of Hazardous Substances (RoHS)**
  - EU Directive banning "placing on market" new electronic equipment containing specific levels of the following after July 1, 2006
    - **Lead**, Cadmium, Mercury, hexavalent chromium, polybrominated biphenyl (PBB), polybrominated diphenyl ether (PBDE) flame retardants
- **Waste Electrical and Electronic Equipment Directive (WEEE)**
  - EU directive sets criteria for collection, treatment, recycling
  - Makes the *producer responsible*
- Related legislation in place or underway in China, Japan, Korea, California, and EU
- REACH will impact even more chemicals and materials

In perspective

- U.S. is excluded from RoHS and most other legislation
  - Most Government systems are not sold outside the U.S.
- Foreign military sales and foreign operations are a concern
- Not all systems can (or need to) be manufactured using MIL-SPEC components

The lead-free transition can impact any program regardless of whether the program itself is exempt or bound by environmental regulations.

Microelectronics Challenges for Defense Systems

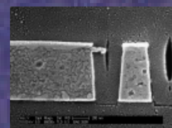
- Increased use / reliance on microelectronics ("Smart" systems)

  - Essential technology for all military missions
    - Strategic, tactical, C4I, special ops
    - "Critical" DoD technology
  - Enabling technology for adaptive operations, transformational opportunities & spiral development

Microelectronics Challenges for Defense Systems

- Extended system life cycles (20 – 40 years)
  - Rapidly evolving, expanding missions
    - Asymmetric threats
    - New capability requirements

  - Increased performance degradation issues



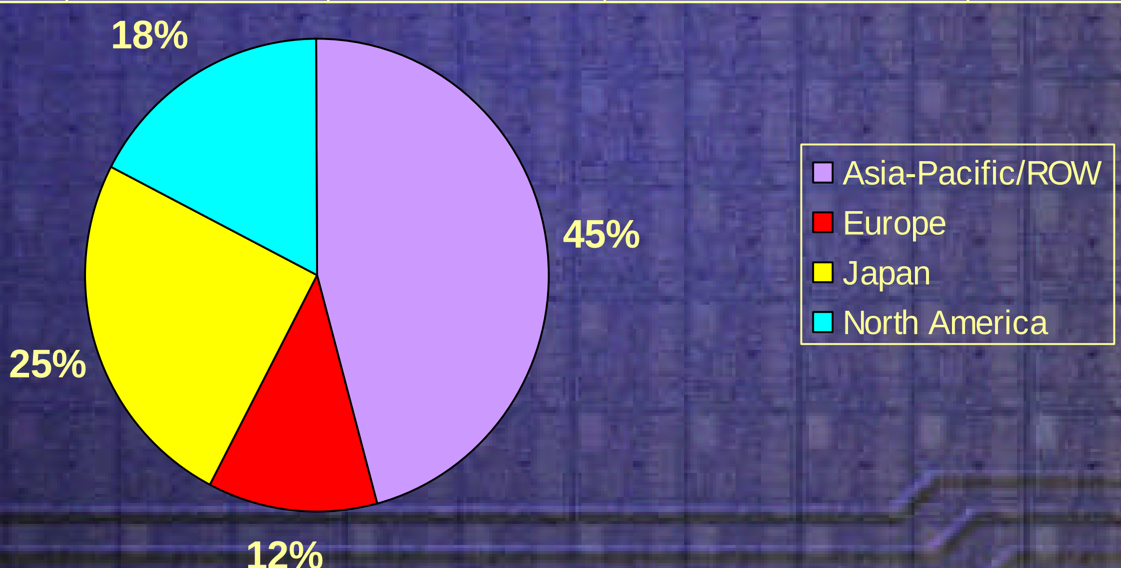
  - Diminishing Manufacturing Sources (DMS)
    - Dynamic development drives obsolescence cycles of 18 months or less
    - Over 90% of all DoD DMS cases are electronics

Microelectronics Challenges for Defense Systems

- Commercial requirements dictates the technology & market
  - Very high volumes for short terms
  - Lower environmental & quality thresholds
  - Unsecure manufacturing / distribution

Regional Distribution of Currently Operational Fabs (2008)

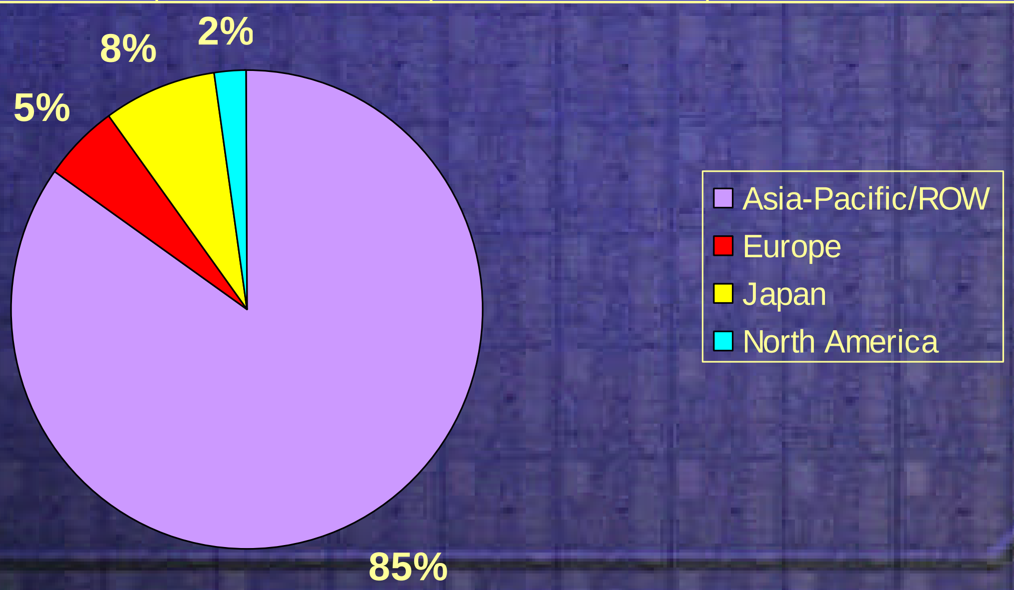
	Number of Fabs	Percent of Total	Capacity in Equiv 8-inch Wafers	Percent of Total
Asia-Pacific/ROW	230	24%	7,842,695	45%
Europe	173	18%	2,003,693	12%
Japan	288	30%	4,238,406	25%
North America	267	28%	3,015,132	18%
Totals	958		17,099,926	



Source: World Fab Watch – Jan 2008

Regional Distribution of Probable Future Fabs (2014)

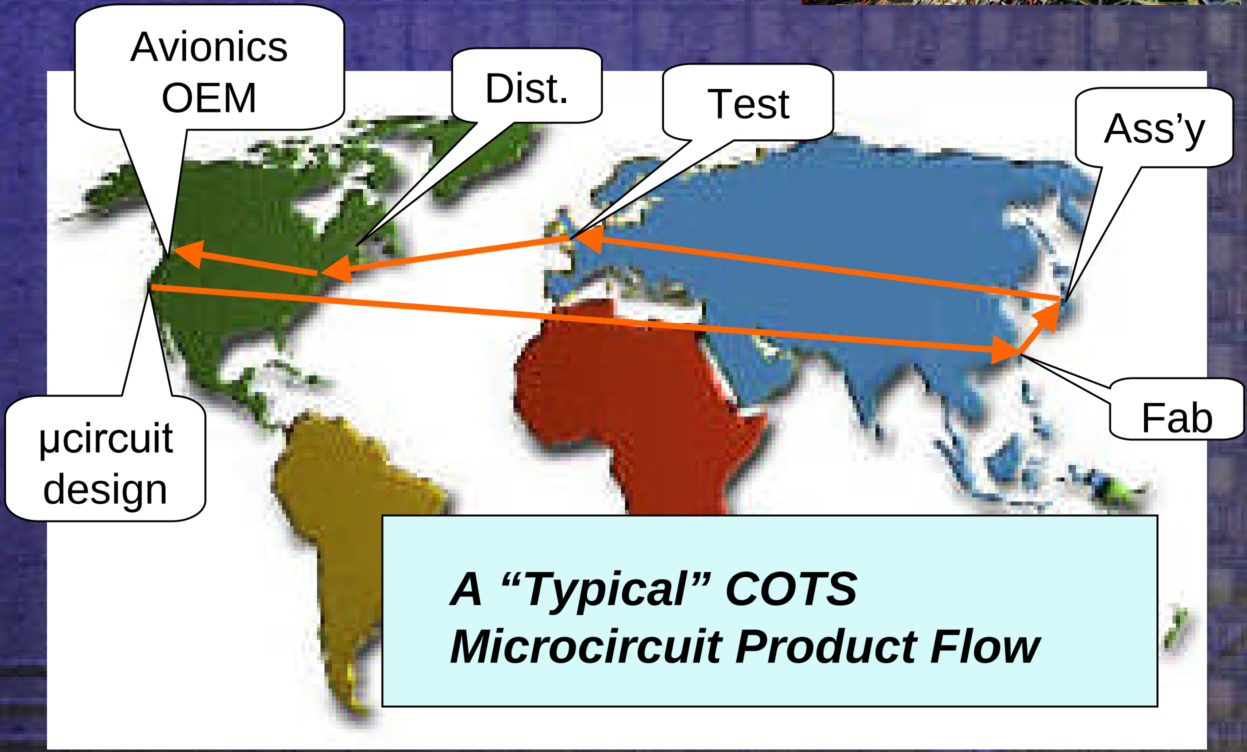
	Number of Fabs	Percent of Total	Capacity in Equiv 8-inch Wafers	Percent of Total
Asia-Pacific/ROW	71	82%	5,480,413	85%
Europe	10	11%	340,238	5%
Japan	2	2%	502,500	8%
North America	4	5%	137,903	2%
Totals	81		6,461,053	



Source: World Fab Watch – Jan 2008

Where Do Your Parts Come From?

The COTS microcircuit chain is….circuitous. The number of potential combinations of links is large, and growing. The level of “control” is shrinking.



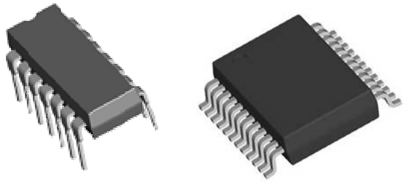
A “Typical” COTS Microcircuit Product Flow

The mil/aero challenge is significantly different

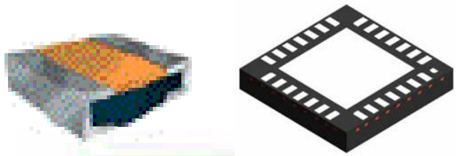
	Commercial airplane	Military airplane	Missile	Satellite	Laptop computer
Useful life	***30 yrs.***	***40 yrs.***	***20 yrs.***	***15 yrs.***	***3 yrs.***
Op. hrs./yr.	***6,000 hrs.***	***< 1,000 hrs.***	***< 1 hr.***	***8,760 hrs.***	***2,000 hrs.***
Technology node	***SOA - 2***	***SOA - 4***	***SOA - 5***	***SOA - 7***	***State-of-the-art***
Environment	***Rugged***	***Rugged***	***Harsh***	***Harsh***	***Benign***
Consequences of failure	***High***	***High***	***High***	***High***	***Low***
Reparable?	***Yes***	***Yes***	***Yes***	***No***	***No***
Development cycle	***7 yrs.***	***10 yrs.***	***11 yrs.***	***15 yrs.***	***< 1 yr.***

How Lead-Free affects the product

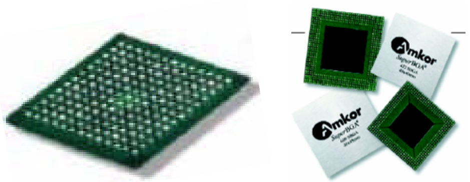
Leadframe Finish



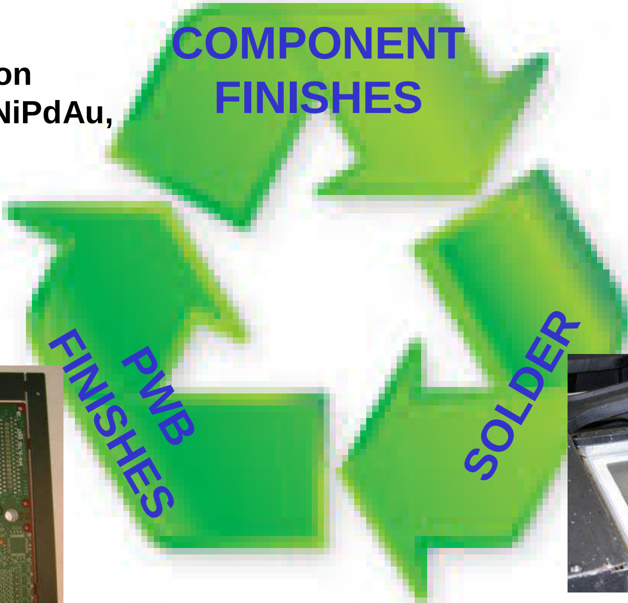
Leadless Termination Finish

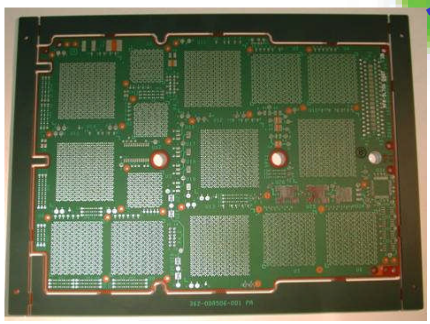


BGA Solder Balls



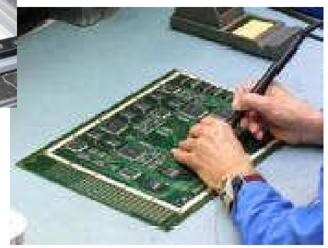
Common Lead-free finishes on current products: matte tin, NiPdAu, SnAgCu





Wave

Paste



Wire

Today: SnPb solders

Today: Tin-Lead HASL
Tin-Lead plate and fused

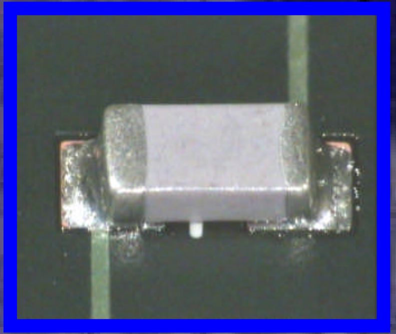
Also: connectors, lugs, cardguides, packages, lids, etc.

Why are Lead-Free Electronics a problem?

- Military (and Aerospace/High Performance) systems have unique requirements:
  - High reliability and critical systems
  - VERY long service life
  - Extended temperature ranges
  - Repairable systems
- DoD acquisition programs are increasingly dependent on ***commercial*** electronic parts and assemblies (COTS)

Lead-Free Solder Issues

- **Manufacturing**
  - Prevailing Lead-free solder replacement (SnAgCu) has ~***35°C higher*** reflow temperature
  - Can affect components and board material
  - Infant mortality / Latent failures
  - Requalification?



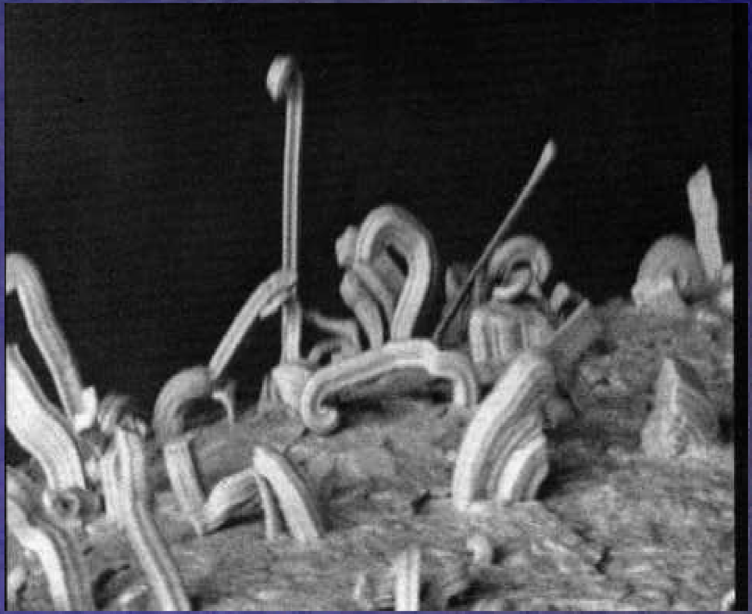
- **Solder joint reliability (durability)**
  - Lead-free alloys can fail in high stress/strain applications
  - Intermetallics between solder and lead/pad
  - Cross contamination of different alloys
  - Changed / unacceptable wetting characteristics
  - New qualification parameters

Cracked Solder Joint

- **Configuration control**
  - Must prevent mixing of incompatible alloys
  - Many components not uniquely identified
  - Repair/Rework

Tin Whisker Impacts

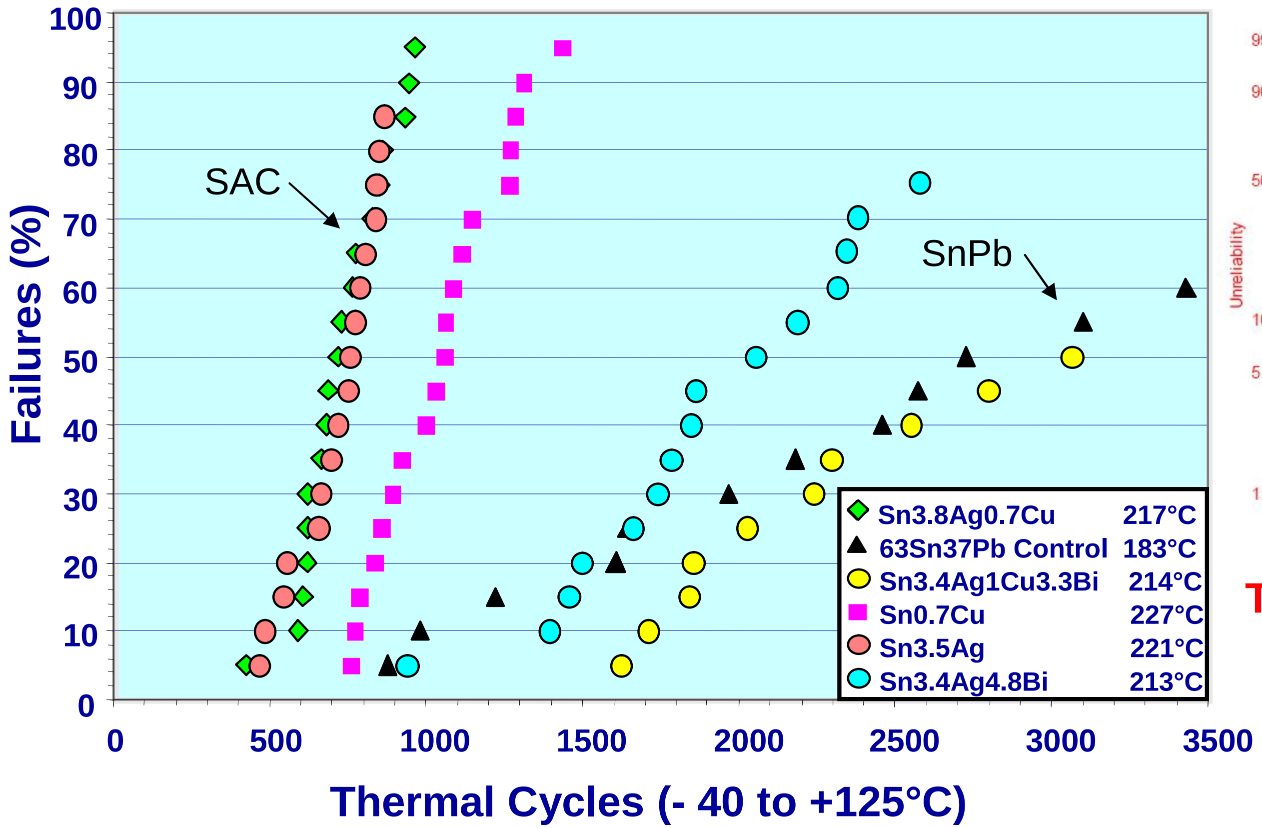
- **Tin whisker effects documented since the 1940's**
- **Tin Whiskers**
  - "grow" from nearly all tin alloys
    - pure Sn (<3% Pb)
    - SnBi, SnCu, SnAgCu
    - Few microns to over 10 mm
  - Electrically conductive
  - Crystalline

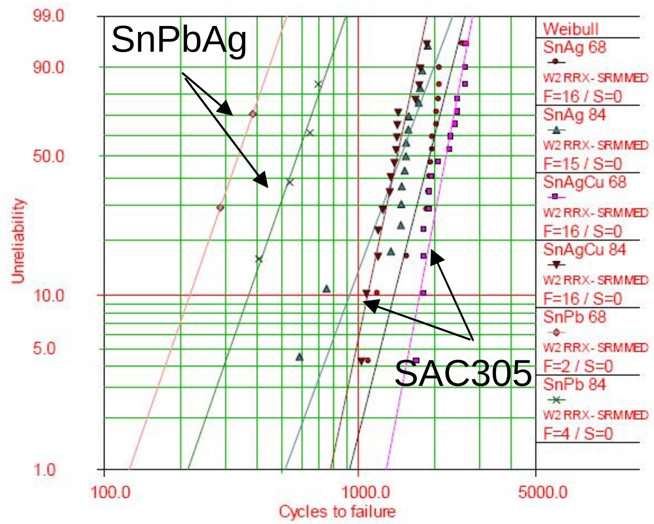


(Photo courtesy of NASA Goddard Space Flight Center)

- **Whisker induced failures:**
  - *Short Circuit* – bridges two adjacent pins
  - *Metal vapor arc* – high voltage and specific atmosphere can result in plasma arc capable of catastrophic damage
  - *Contamination* – whisker breaks off and interferes with mechanical, optical, or MEMS component

Pb-free solder interconnect fatigue in temperature cycling





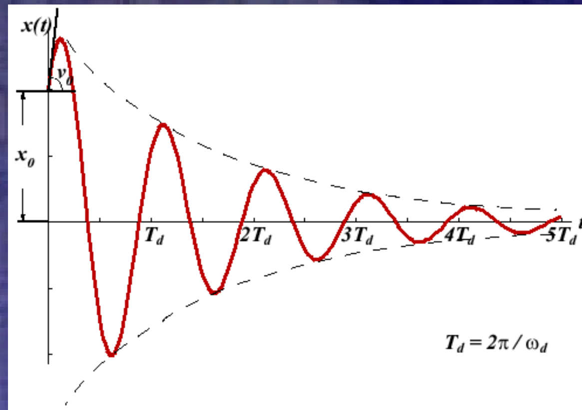
Thermal Cycles (-50 to +50 °C)

Higher strain range, Sn-Pb better than SAC Pb-free

Opposite is true for lower temperature ranges.

Vibration/shock loading – Little data available

- Vibration/shock performance was a tough topic with Sn-Pb solder
- Vibration/shock: Not much available data
  - Cell phone drop-shock testing driving consumer electronics industry
- *Combined* vibration and temperature cycling: Not much data available

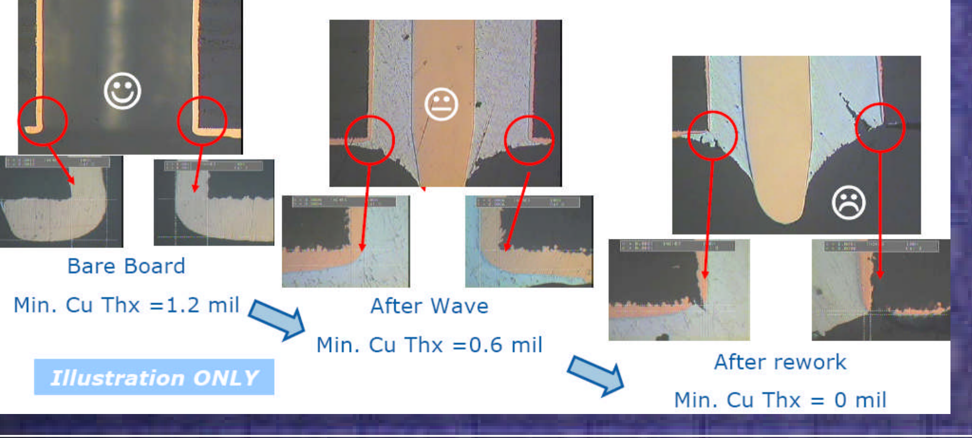


Ref: Meschter DMSMS 2006

What heritage Sn-Pb tests need to be different for Pb-free?

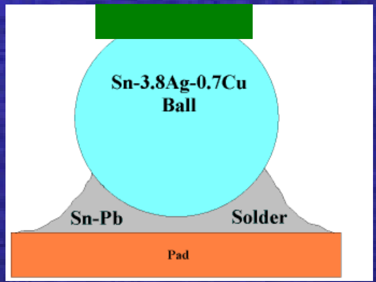
Copper dissolution

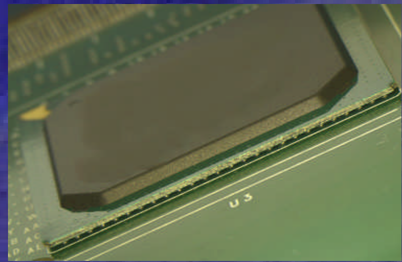
- Copper dissolves when in contact with SAC alloys
  - Higher temperature + High Sn = High dissolution
  - Need to leave enough copper for subsequent repair

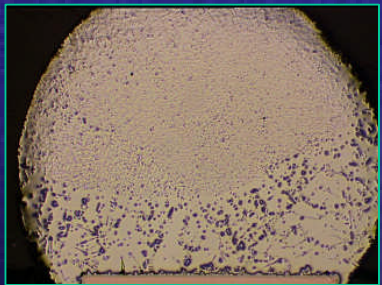


Ref: Meschter Boeing Lead-free conference, Anaheim Nov. 15, 2007

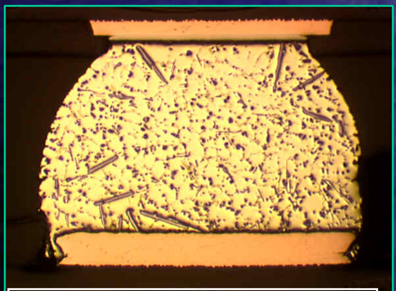
BGAs: Mixing of alloys – today's problem





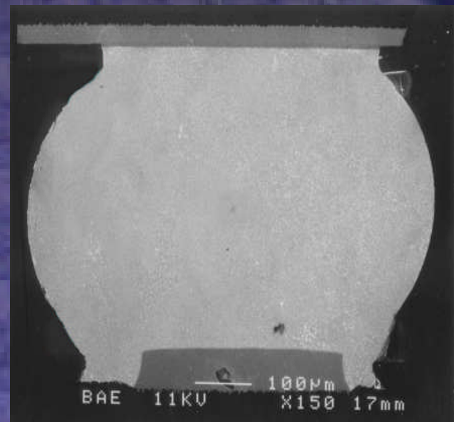


Undesirable joint:
A moderate volume of Sn-Pb results in *partial* dissolution of Pb-free ball



A little better joint:
More Sn-Pb results in a fairly *uniform* composition and phase distribution.
-Tighter solder process window required

P. Snugovsky
Celestica (2006)



Best Solder Joint:
Un-Mixed BGA solder Ball
- Part pad evaluation needed

Un-Mixed BGA solder ball has higher reliability

Ref: Meschter Boeing Lead-free conference, Anaheim Nov. 15, 2007

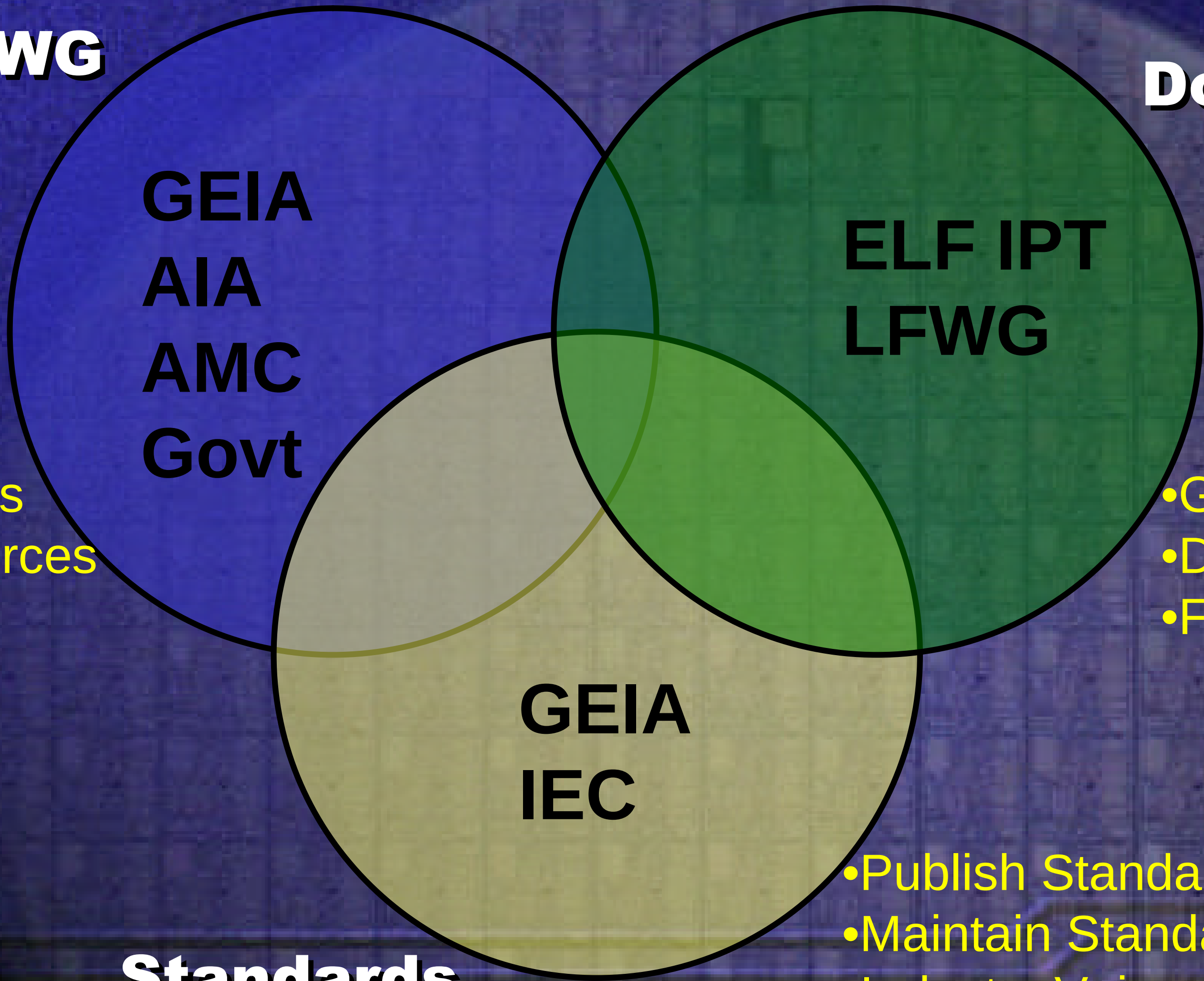
Lead-free Impacts and Concerns

- Proliferation and instability of materials and finishes
- Lack of test and qualification data in harsh environments
- Design, Development and Production Processes
- Repair and Rework Processes
- Cost
- Configuration control of component supply chain

A Comprehensive Strategy

LEAP-WG

- Stakeholders
- Tech Resources
- “Experts”



DoD

- Gov Access
- DoD Policy
- Funding

Standards

- Publish Standards
- Maintain Standards
- Industry Voice

Lead-free Guidance Documents

- **GEIA-STD-0005-1** Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder
- **GEIA-STD-0005-2** Standard for Mitigating the Effects of Tin in Aerospace and High Performance Electronic Systems
- **GEIA-HB-0005-1** Program Management / Systems Engineering Guidelines for Managing the Transition to Lead-free Electronics
- **GEIA-HB-0005-2** Technical Guidelines for Aerospace and High Performance Electronic Systems Containing Lead-free Solder
- **GEIA-STD-0005-3** Performance Testing for Aerospace and High Performance Electronics Containing Lead-free Solder and Finishes
- **GEIA-HB-0005-3** Rework and Repair Handbook To Address the Implications of Lead-Free Electronics and Mixed Assemblies in Aerospace and High Performance Electronic Systems
- **GEIA-HB-0005-4** Impact of Lead-Free Solder on Aerospace Electronic System Reliability and Safety Analysis
- **GEIA-XX-0005-X** Proposed document regarding Configuration Control

Conclusion

- Military, aerospace, and high performance electronics systems have increased challenges due to environmental initiatives
- We must better engage the supply chain
- We must continue to develop technical solutions
  - *"Engineers will have to be engineers"*
- We must continue to develop agile, adaptive design and manufacturing processes to accommodate the rapidly changing global electronics industry

*The DoD must **continue** to field reliable and supportable systems to meet mission requirements*